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NANOTECHNOLOGIES TODAY

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Coal and diamonds, sand and computer chips, cancer and healthy tissue: throughout history, variations in the arrangement of atoms have distinguished the cheap from cherished, the diseased from the healthy. Arranged one way, atoms make up soil, air, and water; arranged another, they make up ripe strawberries. Arranged one way, they make up homes and fresh air; arranged another, they make up ash and smoke.

Our ability to arrange atoms lies at the foundation of technology. We have come far in our atom arranging, but our spacecraft a still crude, our computers are still stupid, and the molecules in our tissues still slight into disorder, first destroying health, then life itself. For all our advances in arranging atom, we still use primitive methods. With our present technology, we are still forced to handle atoms in unruly herds.

But the laws of nature lives plenty of room for progress, and the pressures of world competition are even now pushing us forward. For better or for worse, the greatest technological breakthrough in history is still to come.

Two stiles of technology

Thirty thousand years ago chipping flints was the high technology of the day. Our ancestors grasped stones containing trillions of trillions of atoms and removed chips containing billions of trillions of atoms to make their axe heads. The ancient style of technology handles atoms and molecules in bulk, call it bulk technology.

But the new technology will handle individual atoms and molecules with control and precision, call it molecular technology.

Molecular technology today

One dictionary definition of machine is “any system, usually of rigid bodies, formed and connected to alter, transmit, and direct applied forces in a predetermined manner to accomplish a specific objective, such as the performance of useful work”. Molecular machines fit this definition quite well.

To imagine these machines, one must first picture molecules. We can picture atoms as beads and molecules as clumps of beads. An essential note - molecular bonds are not sharp – it can be broken or reformed.

The things around us act as they do because of the way their molecules behave: air holds neither its shape nor its volume (molecules move freely, bumping and ricocheting through open space), water holds a constant volume as it changes shape (molecules stick together as they move about)… Simple molecular patterns make up passive substances; more complex patterns make up the active nanomachines of living cells.

Biochemists already worked with these machines, which are chiefly made of protein, the main engineering material of living cells. These molecular machines have lumpy surfaces and unusually flexible, but like all the machines, they have parts of different shapes and sizes that do useful work. All machines use clumps of atoms as parts. Protein machines use very small clumps.

Biochemists dream of designing and building such devices, but then they combine molecules in various sequences, they have only limited control over how the molecules join.

Genetic engineers are already showing the way – they build specific DNA molecules by combining molecules in particular order. These molecules are the nucleotides of DNA (the letters of genetic alphabet) , and genetic engineers direct the machine to add different nucleotides in a particular sequence to spell out a particular message. By itself DNA is fairly worthless molecule – it has no practical use, but it led scientists to the proteins. They are, like DNA, resemble strings of lumpy beads. But ulike DNA, protein molecules fold up to form small objects able to do things. It's enzymes and hormones. Nowadays genetic engineers can produce them cheaply by directing the cheap and efficient molecular machinery inside living organisms to do the work.

Existing protein machines

The protein hormones and enzymes selectively stick to other molecules, their behavior more often described in chemical terms. An enzyme changes its target structure, then moves on; a hormone affects its target's behavior only so long as both remain stuck together.

But other proteins serve basic mechanical functions. Some push and pull, some act as cords or struts, and parts of some molecules make excellent bearings. The machinery of muscle, for instance, has gangs of proteins that reach, grab a "rope" (also made of protein), pull it, then reach out again for a fresh grip; whenever you move, you use this machines. Amoebas and human cells move and change shape by using fibers and rods that act as molecular muscles and bones. A reversible, variable-speed motor drives bacteria through water by turning a corkscrew-shaped propeller. If a hobbyist could build tiny cars around such motor, several billions of billions would fit in a pocket, and 150-lane freeways could be built through your finest capillaries.

Designing with protein

How far off is such ability? Steps have been taken, but much works remains to be done. Biochemists have already mapped the structures of many proteins. With gene machines to help write DNA tapes, they can direct cells to build any protein they can design. But they still don't know how to design chains that will fold up to make proteins of the right shape and function. The forces that fold proteins are weak, and the number of plausible ways a protein might fold an astronomical, so designing protein from scratch isn't easy.

But biochemical engineers working on it every day – some of them have designed a protein with properties like those of mellitin, a toxin in bee venom; some of them modifying existing enzymes, changing their behavior in predictable ways. Our understanding of proteins is growing daily.

In the past, according to biologist Garratt Hardin, some geneticists called genetic engineering impossible; today, it is an industry. Biochemistry and computer-aided design are now exploding fields, and as Frederick Blattner wrote in the journal Science, "computer chess programs have already reached the level below the grand master. Perhaps the solution to the protein-folding problem is nearer then we think".